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Technological Diffusion, Learning and Growth:

An Empirical Investigation of a Set of Developing Countries

LUISA ZANFORLIN

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LUISA ZANFORLIN

BADIA FIESOLANA, SAN DOMENICO (FI)

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European University Institute
Badia Fiesolana
I – 50016 San Domenico (FI)
Italy

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Luisa Zanforlin
European University Institute
and International Monetary Fund
E-mail lzanforlin@imf.org

Abstract:

This paper investigates the effects of technological diffusion and learning by doing, as represented by imports of equipment, on a set of middle income countries. Evidence supports a positive, though not linear, relationship between imported equipment on growth. The estimated structure suggests there may be substantial increases in productivity to be gained for less industrialized countries by learning from imported equipment.

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Introduction

The economic literature has long emphasized the role of technology, learning and education in the process of economic growth. In particular, new growth theory (Grossman and Helpman 1991, Romer and Rivera-Batiz 1992, Aghion and Howitt 1992, etc) and evolutionary economics (Dosi, Pavitt and Soete 1990) have stressed the importance of R&D activities in increasing productivity.

Empirical researchers have attempted to evaluate size of the impact of technological progress on growth rates. One of the problems lies in finding measurable variables that can be taken as proxies for technology. Technological development is often represented by R&D expenses over total costs, in some cases it has been measured by the number of new patents registered within a certain period (Griliches 1991). De Long and Summers (1991), following the same line of reasoning as the vintage models, suggest that technology is embodied in machinery.

Research reports evidence of positive association of R&D activities and technological progress in developed countries. There is, however, scarce evidence of effects of R&D on developing countries' catch-up process. Developing countries will not always be able to pursue their own R&D activities because of a lack of means and of educated personnel. Possibly, only the more industrialized countries will conduct R&D activities, in which they have a comparative advantage. The technological transfer process is then a relevant matter for the developing world. According to new growth theories, the process of catching up will be more a matter of acquisition and implementation of new technologies and abilities than of mere capital accumulation in itself. How does such a process occur, which conditions make it possible and what is the size of its impact on developing countries, are all matters still to be analysed.

In applied work, a typical proxy for the probability of coming into contact with foreign technology, and catching up, is the "openness " of a country (Edwards 1991, 1993). This index is usually constructed with various degrees of information on the trading structure, at times the trade dependency ratio* at times more complicated indexes which account for the tariff structure (Edwards, 1993 Barro and Lee 1994).

De Long and Summers (1991, 1992) suggest that the impact on growth of equipment investment is due to productivity effects coming from learning by doing processes. In some classifications of technological content (Wakelin 1995) machinery appears as the category which presents the highest number of innovations produced and used per certain period of time. Machinery could then be thought of as a possible means for technological transfer because of the technology it embodies and of the learning by doing effects it induces.

* Total imports plus total exports over gdp.

The aim of this paper is to use imports of equipment as a proxy for the amount of foreign technology which is transferred and implemented in a developing country and to evaluate the magnitude of the apparent impact of such imports on economic growth compared to the effects of machinery investment reported by De Long and Summers (1991, 1992). In this respect, the impact of imports of equipment on the developing world should then be comprehensive of the dual impact of investment in equipment and of the foreign technology transfer process.

The paper is organized as follows: section 1. presents the model, the data and the estimation techniques, section 2 presents the main results and section 3. briefly draws some conclusions.

Section 1. Data Description and Quantitative Methods.

Imports of equipment are thought to be relevant for developing countries because of two main factors. First, imports of equipment can be taken as a good index of the flow of foreign technology into the country, because of the embodied technology, as reported in some classifications of technological content (Wakelin 1995). Imports of equipment can then represent a narrower definition of the "openness" concept, which should enable countries to enter the catch up path. Second, imports of equipment will increase equipment investment and therefore increase total production. In the literature, imports of equipment have been considered a good approximation for developing countries total investment in machinery equipment. This is explained by suggesting that most developing countries import all their machinery, (De Long and Summers, 1991, 1992).

In the literature, the role of equipment imports as a source of equipment investment and as a channel of international technological transfer can also be found in the analyses of Bloomstrom, Lipsey and Zejan (1992), Romer (1993) and Lee (1994).

1.1 Sample selection.

A sample of 15 countries was selected. The year of selection for the sample is 1960, the closest possible to the beginning of the period of interest. As noted by De Long (1989) and Taylor (1980), in this way the sample will not exclude countries that in theory could have developed high growth rates: i.e. countries that a priori had the same features as those that did grow, and yet failed to do so.

Countries in the sample were required to be middle income. This was set to assure that countries have reached a minimum level of income and of technological capability to allow a catch-up process to take place. For this reason the poorest 30% of countries, were excluded from the sample as well as former communist countries and oil exporting countries. The richest 20% of countries were also excluded because equipment imports, as channels of international technological transfer, are assumed not to be relevant for developed, human capital abundant countries. This sample roughly coincides with the a set of middle productivity countries, cut at the same percentiles on the distribution of labour productivity, where labour productivity is represented by gdp per worker. All of the countries in 1960, except for Argentina, have a labour productivity level below the lowest cut-off for which De Long and Summers (1992) conduct their analysis on the income stratified sample (pag. 173, Table 7, column 4, third line).

The analysis uses data from countries which are: a) in the higher 60% of the size distribution of gdp, constituting the world economy, b) the size of the manufacturing sector represents at least 10% of total gdp, and c) total imports of the country exceed 0.5% of total imports in the developing world.

1.2 Econometric techniques[1].

The data set covers the period 1955 to 1990, it was divided into seven periods of five years. The regressions were run over the period 1960-1990 in order to use lagged period explanatory variables.

The data for imports of equipment were taken from the UN Yearbook of International Trade Statistics and they include section 7 of the SITC classification. Investment data were taken from Summers and Heston PWT5, as were data for total gdp and gdp per worker. Growth of labour was proxied by the growth of total active population and data were taken from the ILO statistics and World Bank Indicators of Social Development. Human capital was proxied by secondary school enrollment ratios, and was taken from UNESCO yearbooks and World Bank Indicators of Social Development. The trade dependency ratio was calculated from UN Yearbook of International Trade Statistics data.

The dependent variables were chosen to be growth of total gdp, and growth of gdp per worker. Gdp data was available on a yearly basis, and growth rates were calculated as the five year period average of the annual rates. However, since such rates presented a considerable variance, logarithmic transformations of the levels of total gdp and of gdp per worker were introduced. Annual growth rates were then calculated as the difference of the

[1] See Appendix A for data definitions and sources.

logarithms, and again the five year period growth rate was calculated as the average of the annual growth rates.

Imports of equipment were calculated as shares on gdp and so was the investment net of imports of equipment (ineq) variable. These variables were included at beginning of period values to control for endogeneity. To further control for this, some regressions were run on data that had been lagged two and five years (Table 1a. and 2a column 4 and 5).

Investment data, calculated as shares of gdp was also entered at beginning of period values.

The growth of labour, represented by growth of active population, was lagged five years to account for possible endogeneities.

The growth of human capital was proxied by growth in secondary school enrollment ratios over the five year intervals, this was calculated using the beginning and end of period values of the ratio. Initial levels of human capital were proxied by levels of secondary school enrollment ratios. Both these variables were lagged five years before the beginning of period, so to allow for time out of school before the employment of human capital.

Initial conditions were proxied by a variable representing the technological gap. In the case the dependent variable was the growth of the log real gdp per worker, the gap was calculated as logarithm of the ratio of per worker gdp of a country over the per worker gdp in the US. In the case the dependent variable was total gdp, then the gap was calculated using per capita gdp. In all cases the variable representing the gap entered the regression at beginning of period values. To further control for possible correlation with other explanatory variables, a regression was run where the gap variable was lagged 5 years before the beginning of period (Table 1a and 2a eq. 8).

In its simplest version the growth equation estimated is described by:

$$\Delta \ln Y_{i,t} = C + C_i + C_t + \beta_1 \ln gap + \beta_2 imeq + \beta_3 ineq + \beta_4 \Delta h + \beta_5 \Delta l + \varepsilon_{i,t}$$

where imeq and ineq represent imports of equipment and investment net of imports of equipment respectfully, and l and h represent labour and human capital.

The model was set up as a panel of 15 countries pooled over 7 periods. The pooled model was tested against fixed or random country and period effects. Pooled data analysis allows one to account for individual heterogeneity and for individual specific effects in the structure of errors between cross-sectional units. The econometric structure of the model was then derived from a series of tests on the pooled data.

In all cases, the hypothesis of no country effects was rejected against the alternative of fixed country effects, and the hypothesis of random country effects was rejected against the alternative of fixed country effects (Hausman test).

In the model under consideration, fixed country effects are collinear with variables which change little, such as land per capita, mortality rates, fertility rates, primary school enrollment rates and the like. Therefore, such variables were not individually included in the regression.

In all cases the hypothesis of no period effects was rejected against an alternative of fixed period effects and in the majority of cases the hypothesis of random period effects was rejected against fixed period effects.

As above in the case of country effects, fixed time effects come to represent period specific variables such as state of the business cycle etc. that affect all countries at the same point in time, as such variables not individually included in the equation.

In all cases the hypothesis of time effects only was rejected against the alternative of fixed country and time effects (two-way fixed effect model). The hypothesis of country effects only was also rejected against the two-way fixed effects model. Because of these results, the two-way fixed country and period effects model was considered as an adequate econometric method.

The model was also estimated introducing continental effects[2] rather than single country effects. This method would leave more degrees of freedom for the estimation. In all cases the hypothesis of no continental effects was rejected against the continental effects alternative. The two-way fixed effects estimator was still considered adequate.

The continental effects model, however, has a lower R^2 than the country effects model. This is probably due to the great importance of country specific variables, which were not specifically accounted for, but were introduced in the form of country dummies.

[2] Continental dummies are Latin America, Asia and Europe.

Table 1a*.

Dependent variable: growth log real gdp.

Period: 1960-1990.

Estimating techniques:
(a) two way fixed country and period effects.

Table 1a.

	1	2	3	4	5	6	7	8	9
lgap	-.030 (.015)	-.031 (.015)	-.031 (.015)	-.029 (.015)	-.023 (.015)	-.022 (.016)	-.031 (.015)		-.030 (.015)
lgap-5								-.006 (.006)	
imeq	.078 (.064)	.078 (.066)	.083 (.060)			.087 (.046)		.045 (.062)	.080 (.064)
ineq	-.010 (.048)					-.002 (.048)			
h	.140 (.065)	.143 (.064)	.141 (.064)	.141 (.046)	.141 (.066)	.138 (.048)	.145 (.062)	.160 (.067)	.143 (.066)
lab	.44 (.25)	.42 (.26)	.43 (.26)	.46 (.27)	.58 (.25)	.50 (.27)	.43 (.25)	.58 (.28)	.41 (.27)
invs		.011 (.063)							
imeq-2				.074 (.072)					
ineq-2				-.005 (.023)					
imeq-5					.005 (.064)				
ineq-5					-.024 (.046)				
lag rgdp						-.216 (.322)			
imeq+5							.069 (.048)		
secer									.9E-04 (.5E-03)
R^2 Ad.R^2	.66 .53	.66 .52	.65 .53	.65 .51	.61 .46	.66 .52	.66 .53	.65 .52	.66 .52

* Standard errors in parenthesis.

Definitions and sources in Appendix A.

Table 1b*

Dependent variable: growth log real gdp.

Period: 1960-1990.

Estimating technique:
(a) two way fixed country and period effects.
(b) fixed time and continental effects.

	1 (a)	2 (b)	3 (b)	4 (b)	5 (b)	6 (b)
lgap	-.030 (.016)	-.008 (.010)	-.008 (.011)	-.007 (.010)	-.024 (.013)	-.008 (.010)
imeq		.029 (.055)	.025 (.058)		.028 (.059)	
ineq			.010 (.047)			
h	.126 (.068)	.108 (.064)	.106 (.065)	.113 (.064)	.143 (.067)	.104 (.067)
lab	.42 (.27)	.43 (.26)	.44 (.26)	.47 (.26)	.47 (.25)	.44 (.26)
invs	.028 (.058)			.012 (.057)	.028 (.059)	
open	.014 (.012)					.005 (.010)
secer					.2E-03 (.2E-03)	
R^2	.66	.63	.63	.63	.65	.63
AR^2	.52	.51	.51	.52	.52	.51

* Standard errors in parenthesis.

Definitions and sources in Appendix A.

Table 2a.*

Dependent variable: growth log real gdp per worker.
Period: 1960-1990.

Estimating technique:
(a) two way fixed country and period effects.

Table 2a.

	1	2	3	4	5	6	7	8	9
lprgap	-.023 (.018)	.023 (.018)	-.021 (.018)	-.036 (.018)	-.036 (.018)	-.021 (.018)	-.018 (.021)		-.023 (.018)
lprgap-5								.005 (.023)	
imeq	.113 (.067)	.087 (.067)	.099 (.060)				.127 (.069)	.083 (.062)	.113 (.062)
ineq	.016 (.053)						.044 (.053)	-.007 (.053)	
h	.180 (.069)	.182 (.069)	.177 (.069)	.180 (.069)	.177 (.071)	.182 (.069)	.175 (.069)	.193 (.071)	.170 (.069)
lab	.182 (.27)	.187 (.27)	.180 (.27)	.29 (.29)	.32 (.27)	.22 (.27)	.21 (.29)	.39 (.34)	.25 (.29)
invs		.039 (.069)							
imeq-2				.064 (.074)					
ineq-2				-.028 (.051)					
imeq-5					.046 (.067)				
ineq-5					-.007 (.046)				
imeq+5						.083 (.048)			
lag gdp/w							-.262 (.34)		
secer									-.2E-03 (.4E-03)
R^2 AR^2	.61 .46	.61 .46	.61 .47	.60 .45	.60 .44	.61 .47	.61 .46	.60 .45	.61 .46

* Standard errors in parenthesis.

Definitions and sources in Appendix A.

Table 2b.*

Dependent variable: growth log real gdp per worker.

Period: 1960-1990.

Estimating technique:
(a) two way fixed country and period effects.
(b) fixed time and continental effects.

	1 (a)	2 (b)	3 (b)	4 (b)	5 (b)	6 (b)
lprgap	.032 (.018)	-.005 (.007)	-.1E-04 (.005)	-.002 (.078)	-.007 (.007)	-.036 (.018)
imeq		.007 (.048)	.018 (.048)	.062 (.060)		.018 (.048)
ineq				.048 (.039)		
h	.147 (.071)	.097 (.064)	.092 (.067)	.092 (.064)	.090 (.064)	.163 (.069)
lab	.122 (.27)	.216 (.25)	.27 (.23)	.23 (.25)	.175 (.25)	.36 (.25)
invs	.051 (.062)	.069 (.067)			.071 (.069)	.067 (.055)
open	.023 (.009)				.003 (.007)	
secer						.5E-03 (.2E-03)
R^2 AR^2	.63 .48	.45 .36	.44 .36	.45 .36	.46 .37	.49 .40

* Standard errors in parenthesis.

Definitions and sources in Appendix A.

Since the sample of countries is small, it appears to be quite important to check whether the experience of one particular country determines the result.

For this, a set of regressions as in Table 1 column 1 and Table 2 column 1, was run excluding countries that had extreme values on the scatter plot.

Table 3[*]. Outlier Analysis.

Period: 1960-1990.
Econometric technique:(a)

Dependent variable		no sing	no jap	no irl	no irl no sing
lrgdp	imeq	0.136 (0.092)	0.071 (0.05)	0.097 (0.07)	0.198 (0.138)
	ineq	-0.014 (0.05)	0.009 (0.05)	0.023 (0.05)	0.018 (0.05)
lgdp/w	imeq	0.177 (0.11)	0.090 (0.07)	0.120 (0.07)	0.196 (0.138)
	ineq	0.013 (0.05)	0.021 (0.05)	0.044 (0.05)	0.037 (0.07)

A better understanding of the impact of the import of machinery variable on growth is obtained by examining the correlation coefficients against a series of alternative variables. In particular two were thought to be particularly important: a) a tighter definition of machinery, consisting basically of industrial machinery that does not include spare parts and other small electrical equipment, and b) "openness" as defined by the trade dependency ratio. Low correlation with the variable at point a) would indicate that the imports of equipment includes non productive items in the definition; high correlation with the variable at point b) would suggest that high imports of machinery are only part of the general willingness to import, and that the technological transfer effect may come from a variety of different contacts with foreign technology.

To conclude, it must be remembered that the sample under analysis is limited and particularly in the case of correlation coefficients the results should not be considered general.

Table 4. Correlation figures of the imports of equipment variables.

	imeq
mach imp	0.8860
openness	0.8535
invs	0.4936
pop	0.07
secer	0.3240

Definitions and sources in Appendix A.

A final question on the effects equipment imports is whether the structure of the these effects is constant for any level of the variable, or whether it presents a more complicated functional form. Since in this analysis imports of equipment are taken to represent to some extent the process of technological diffusion and learning by watching effects, effects of equipment imports might present a structure of the logistic type, which is the typical functional form presented by diffusion and learning by watching models (Gomulka 1990, King and Robson 1989, 1993) and technology spillovers. Equipment imports might lead to positive productivity effects only within a certain range of imported equipment. If the level of imported equipment were too low, there might be not enough for the economy to be able to benefit form the technology; if it were too high, the economy might have exhausted most of the possibilities of increasing productivity by using foreign technology and therefore the rate of the country's productivity increases would be slowing down.

To test for this structure, the sample was cut at alternative lower and an upper bounds of equipment imports variable and a series of regressions were run. It was not possible to run panel data analysis on the restricted sample because of the loss in degrees of freedom. The cut-off interval was chosen so to maximize R^2 in the regression, wider intervals produce a decrease in R^2 and in the estimated value on the coefficient of the equipment imports variable. Standard errors are high as a consequence of the restriction of the sample, which ranges between 47 to 22 observations. Generally, it appears as if the coefficient on the equipment imports variable is not constant, i.e. there is evidence of a non-linear relationship between the variable and productivity growth.

Table 5*. Truncated Sample Estimations.

Dependent variable: growth log real gdp per worker.

Period: 1960-1990.

Econometric techniques:
(a) ols
(b) ols with continental dummies

	0.04 <imeq imeq>0.15 (a) obs:22	0.04 <imeq imeq>0.15 (b) obs:22	0.02 <imeq imeq>0.18 (a) obs:3	0.015 <imeq imeq>0.20 (a) obs:47
imeq	.99 (.322)	.622 (.414)	.410 (.092)	.230 (.092)
ineq	-.122 (.083)	-.157 (.085)	-.030 (.078)	-.009 (.055)
h	.246 (.237)	.239 (.242)	.154 (.104)	.113 (.094)
lprgap	-.105 (.071)	-.082 (.032)	-.036 (.018)	-.029 (.013)
R^2 AR^2	.47 .35	.56 .38	.31 .24	.20 .19

* Standard errors in parenthesis.

Definitions and sources in Appendix A.

Section 2. Discussion of the estimation results.

On analysis of the first three tables, the important figure that emerges from the estimates, is that the coefficient on the imports of equipment variable is low. It appears to be generally lower than the figure estimated on equipment investment by De Long and Summers (1992). It also appears to be lower than the figure estimated on the stratified sample of countries having per worker productivity below a cut-off level of 0.30 (p.173 cit.1992). The countries in the sample under consideration belong to this category. When country effects are substituted with continental effects, the estimated coefficients for equipment imports fall further still, although there appears to be a worsening of the goodness of fit in such a specification of the model.

Overall there appears to be little evidence substantial endogeneity problems in the estimates of the equipment imports variable. When equipment import data are lagged two or five years, the estimated coefficients do not vary considerably, nor they do in the case the lagged dependent variable is included among the regressors or equipment imports are entered at end of period values.

Excluding particular countries from the sample tended to increase estimated coefficients, especially for in the Singapore and Ireland case, however these differences cannot be considered substantial especially in view of their high standard errors.

The size of estimated coefficient, on the technological gap, indicates that, in the sample under estimation, the dimensions of the catch-up effects are rather modest.

Growth of human capital, as proxied by lagged increases of secondary school enrollment rates, appears to have a considerable impact on productivity growth rates. Levels of the human capital variable, however, appear to have an insignificant impact.

When the openness index was used as an alternative indicator for foreign technology transfer there was no substantial reduction of R^2.

The analysis of the partial correlations presented in Table 4 suggests that the important effect being estimated from the equipment variable does not come from including parts of equipment and replacements in the equipment variable. It does not exclude the possibility that the positive association of equipment imports with growth is part of a more general trade effect, i.e. due to greater imports and exports in general. Moreover, it is not altogether possible to distinguish a separate effect of equipment imports from a more general indicator of human capital level for the countries in the sample.

The final hypothesis of a logistic structure in the effects of imports of equipment appears to gain some support from the estimates obtained in the sample truncated at lower and higher bounds of the import of equipment variable. The coefficients obtained by truncating the interval are considerably higher than those obtained in previous estimations. The narrower interval exhibits the highest estimated coefficient as well as the highest R^2, however, it also presents the greater variance. Progressive increase of the dimensions of the interval lowers the estimated coefficients on the import of equipment variable and reduces the goodness of fit of the regression. This suggests that the impact of equipment imports is highest after a certain level of "learning" is reached. In this stage, there is evidence for a "social return" from equipment, as defined by De Long and Summers (1992), to be higher than the private return. However, after the equipment imports share of gdp has reached a certain level in the economy, the marginal effect of further imports of equipment declines.

Section 3. Conclusions.

In the general sample, the coefficient estimated on the impact of imports of equipment on the growth variables is lower than that reported in De Long and

Summers (1992).

Price data might have had some importance in determining their results. If it had it been possible to include some data on prices of equipment in the equipment imports variable, some of the results presented above would change. The presence of multiple deflators, unaccounted for in the construction of the variables, might be biasing the equipment import variable and therefore its estimated effects. In terms of purely customs values per unit[3], no great differences across countries were found when entering the data. If, however, faster growing countries had lower equipment prices and slower growing countries had higher equipment prices, as maintained by De Long and Summers (1992), the data on fast-growing countries, to some extent, would be underestimating the value of equipment imports; the opposite would be true for slow growing countries. This would probably lead to somewhat higher estimated coefficients on the equipment imports variable.

The econometric technique itself may lead to differences in the estimated coefficient because De Long and Summers do not perform the estimation on a panel but rather a cross section and therefore they did not include country and period effects.

Finally, the high coefficient they obtain might be due to the high productivity of equipment investment in industrialized countries. These countries carry out their own R&D activities and can benefit to a greater extent from innovation and learning.

However, the estimations performed on the truncated sample suggest that international technology transfer, as estimated in the form imported equipment,

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[3] Trade data are entered in the UN Yearbook both in total values and in units or in weight. A very informal analysis of distortions at the customs level can be performed by comparing unit values.

has non linear structure. The productivity effects of importing equipment are large above a certain level of imported equipment, but these tend to die out as imports of equipment reach high levels of gdp shares.

To conclude, it should be noted that imports of machinery will carry the beneficial effects of international technology transfer in the case there should be a productivity differential between the developing's country home production and the imported equipment. In fact, this would occur only in the case of home industry protection, since, if free trade were allowed, a country able to manufacture machinery efficiently and competitively would not import equipment. This also indicates that, in the case of free trade and efficient industrial production of equipment goods, imported equipment cannot be a good proxy for equipment investment. A technological transfer effect could then be noted only by evaluating the differential between the coefficients of home produced equipment investment and imported equipment. The impact of the equipment imports on the growth rate of gdp accounts for different effects which appear to be difficult to interpret.

It would be then interesting that further effort should be given into investigating the ways and possibilities of foreign technology transfer, as well as into measuring the impact of technological development.

References.

Baltagi, B. (1995) *Econometric Analysis of Panel Data.* Wiley.

Bloomstrom, M. Lipsey, and Zejan, M. (1992) "Explaining Growth in Developing Countries" NBER n. 4132.

De Long, J.B. (1988) "Productivity Growth, Convergence and Welfare: a Comment". American Economic Review, 78 n.5:1138-1154.

De Long, J.B. and Summers, L. H. (1991) "Equipment investment and Economic Growth". Quarterly Journal of Economics 106(2):445-502.

De Long, J.B. and Summers, L. H. (1992) "Equipment investment and Economic Growth: How Strong is the Nexus?". Brookings Papers on Economic Activity, 2:157-211.

Dosi,G. Pavitt, K. and Soete, L. (1988) *The Economics of International Technological Change.* Longman.

Edwards, S. (1991) "Trade Orientation Distortions and Growth in Developing Countries". Journal of Development Economics, 39 (1): 31-57.

Edwards, S. (1993) " Trade Policies, Exchange Rates and Growth". NBER n.4511.

Griliches, Z. (1991) "The search for R&D spillovers" NBER n.3768.

Gomulka, S. (1990) *Technology Diffusion and Growth.* Routhledge.

Grossman, G. and Helpman, E (1991) *Innovation and Growth in the Global Economy.* MIT Press.

King, M. and Robson, M. (1989) "The Role of History in Endogenous Growth Models " NBER 3151.

King, M. and Robson, M. (1993) "A Dynamic Model of Investment and Endogenous Growth" In *Endogenous Growth*, T.M. Andersen, and K.O. Moene eds. Blackwell.

ILO: Yearbook of Labour Statistics. Various editions.

Lee, J.W. (1994) "Capital Goods Imports and Long Run Growth" NBER n. 4725.

Romer, P. (1986) "Increasing Returns and Long Run Growth" Journal of Political Economy, 94 (5):1002-1037.

Romer, P. (1993)" Idea Gaps and Object Gaps in Economic Development" Journal of Monetary Economics,

Summers, L. H. and Heston, A. (1991) "The Penn World Table (Mark 5): An Expanded Set of International Comparisons, 1950-1988". Quarterly Journal of Economics, 106 (2):327-368.

UN: Yearbook of International Trade Statistics. Various editions.

UNESCO: Statistical Yearbook. Various editions.

Wakelin, K. (1995) "Empirical Studies on the Relationship between Trade and Innovation" Ph.D. Dissertation, European University Institute, Florence, Italy.

World Bank: World Tables. Johns Hopkings University Press. Various editions.

Zanforlin, L. (1995) "Technological Diffusion, Learning and Economic Performance: an empirical investigation on an extended set of countries" Manuscript, Florence.

Appendix A: **Variable names and sources.**

Dependent variables:

RGDP/W: Gross Domestic Product per Worker; Source: SH PWT5.

RGDP: Gross Domestic Product at 1985 prices; Source: SH PWT5.

Explanatory variables:

ACTPOP: Total Active Population. Source: World Bank Indicators of Social Development and ILO Yearbook of Labour statistics.

IMEQ: Imports of machinery and transport equipment (SITC 7), over GDP; beginning of period values. Source: UN Yearbook of International trade and SH PWT5.

INEQ: Investment net of IMEQ over GDP; beginning of period values. Source: SH PWT5.

INVS: Investment share of GDP; beginning of period values.Source SH PWT5.

LGAP: Logarithm in base e of the per capita income gap with respect to the U.S., (y_c/y_{us});beginning of period values. Source: SH PWT5.

LPRGAP: Logarithm in base e of the per worker output gap with respect to the U.S, $(GDP/W_c$ / $GDP/W_{us})$; beginning of period values. Source: SH PWT5.

H: Growth of secondary school enrollment rates; average lagged period (5 years) growth rate. Source: World Bank Indicators of Social Development and UNESCO yearbook.

LAB: Growth of active population; average lagged period (5 years) growth rate. source: World Bank Indicators of Social Development and ILO yearbook.

MACHIMP: Import of industrial machinery (SITC 711, 712, 715, 717, 718) as a share of GDP; beginning of period values. Source: UN Yearbook of International trade and SH PWT5.

OPEN: (Total Imports + Total Exports) / RGDP; beginning of period values.

Source: UN Yearbook of International trade and SH PWT5.

POP: Population per square kilometer. Source World Bank Indicators of Social Development.

SECER: Secondary School Enrollment Rates; beginning of period values lagged 5 years .Source: World Bank Indicators of Social Development and UNESCO yearbook

X_x: x years lagged variable.

Lag X: one period (5 years) lagged variable.

Appendix B.

Countries in the Sample

ARGENTINA
BRAZIL
CHILE
COLOMBIA
MEXICO
HONG KONG
JAPAN
KOREA
MALAYSIA
THAILAND
SINGAPORE
GREECE
IRELAND
SPAIN
TURKEY

Years in the Panel:

1955, 1960, 1965, 1970, 1975, 1980, 1985, 1990.

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